SILVA BALCANICA

Silva Balcanica 25(2): 75-83 (2024)
doi: 10.3897/silvabalcanica.25.e125509

RESEARCH ARTICLE

Influence of erosion control afforestation on some soil parameters in two watersheds in Southwest Bulgaria

Eli Pavlova-Traykova

Forest Research Institute, Bulgarian Academy of Sciences, 132, "St. Kliment Ohridski" Blvd.1756 Sofia, Bulgaria

Corresponding author: Eli Pavlova-Traykova (pavlova.eli77@gmail.com)

Academic editor: Miglena Zhiyanski | Received 16 April 2024 | Accepted 3 June 2024 2024 | Published 06 August 2024

Citation: Pavlova-Traykova E. 2024. Influence of erosion control afforestation on some soil parameters in two watersheds in Southwest Bulgaria. Silva Balcanica 25(2): 75-83. https://doi.org/10.3897/silvabalcanica.25.e125509

Abstract

Soil is limited resource with vital role in maintenance of variety ecosystems. One of the greatest treat for soils is soil erosion. This natural hazard is widely spread in the terrestrial world, and the territory of Bulgaria is also affected.

Important role for soil protection has a forest vegetation and afforestation is widely used for erosion control activity. The main benefits of afforestation are reduction of water runoff, erosion and sedimentation year-round, which is important for the areas located around the reservoirs and their basins. They also decrease the migration of vital substances for soils and sedimentation yield.

The main goal of the study is to establish the influence of erosion control afforestation to the main soil characteristics in the territory of two watershed situated in Southwest Bulgaria. Soil samples and dead leaf cover were analyzed as well as some characteristics of afforestation and topographic characteristics.

It was established high water resistance of the soil aggregates under the planted forests and low resistance in the controls. The amounts of content of org. carbon and total nitrogen varying with slope and exposure.

The differences between parameters of soils under afforestation and in control samples is established which shows an important influence of forest to the soil characteristics.

Keywords

Soil erosion, forest vegetation, Dzherman river

Introduction

Afforestation activities have been found to be one of the most successful erosion control practices (Pavlova-Traykova et al., 2021). Tree vegetation has a positive effect on decrease degradation processes, by reducing solid runoff, as well as on improving soil characteristics (Angelov, Bachvarov, 1963; Marinov, 2011).

Planted forests takes about 21% from forest territories in Bulgaria. They were created mainly in the middle of the 20th century with an erosion control purpose and for the restoration of degraded forests (Appendix No. 1.4). The tree species that are mainly used are white pine *(Pinus sylvestris* L.) with 48% and black pine (*Pinus nigra* Arn.) with 41%. The main reason for this is their ecological characteristics like relatively easily grow on different soils, including eroded ones (Panayotov et al., 2016).

A large part of the planted forests are in good health and showed high productivity, but there are with deteriorated health and suffer from various damages and disturbances.

One of their problems though have been staked since their inception (Popov et al., 2018). Planted forests was carried out at high densities over 10,000 number per hectare, and in one period it is forested even several in one hole, which is far away from recommended by Regulation on the terms and conditions for afforestation (Regulation 2, 2013) 2500-3000 number per hectare. The aim was to quickly form a forest environment and restoration of the ecological functions of the forest, provision of maximum protective effect, elimination of erosion processes, increase in productivity and accelerated production of large-scale construction wood from coniferous species (Popov et al., 2018).

Although serious problems are looming in forested areas and it is necessary to take a number of decisions regarding the management of these forests, they have fulfilled their function and strengthened the terrain, reduced erosion processes and improved soil conditions.

The article presents the results for soil characteristics and their connection with afforestation. Different relationships were established based on topographic features and tree species.

Materials and Methods

The study area is situated in Southwest Bulgaria on the watersheds of Bistritsa and Dzhubrena (fig 1.). Bistritsa river is one of the left tributaries of the Dzherman River. The area of the watershed is 56.90km^2 from which 24.13 km^2 are forest territories. The average slope gradient of the watershed is 21° and the average altitude is 1577 m a.s.l (Pavlova-Traykova, 2019).

Dzhubrena river is right tributary of Dzherman river. The area of the watershed is 112.2km^2 of them 41.53km^2 are forest territories (fig 1). The average altitude of the watershed is 1016 m and average slope gradient 11° m a.s.l. (Pavlova-Traykova, Marinov, 2018)

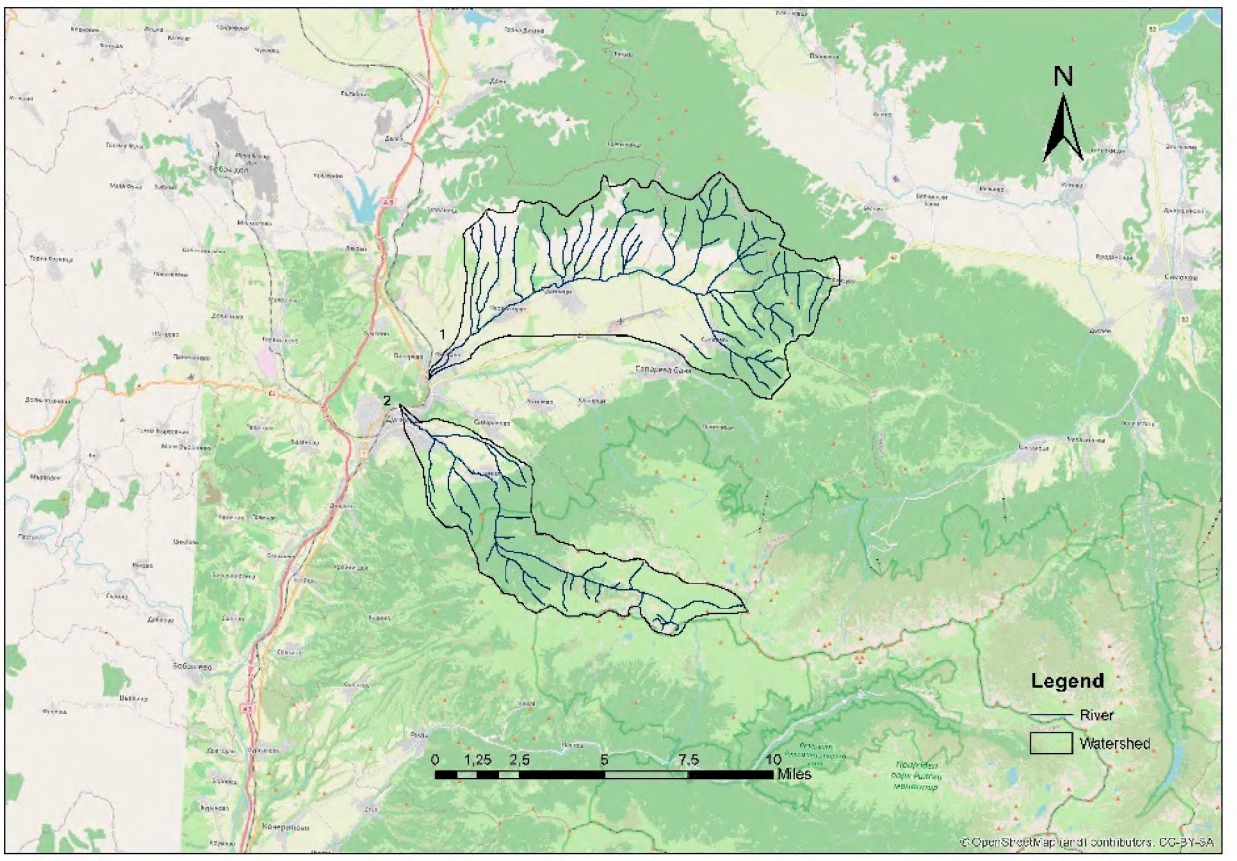

Figure 1. Location of watersheds 1. Dzhubrena and 2 Bistritsa

In the watersheds 17 soil profiles were analyzed. The profiles are 13 formed under the influence of two type of tree species and 4 control samples. In the sample areas (SA), detailed measurements of silvicultural indicators were made, the average height was measured and their afforestation scheme was determined. Soil samples were taken from the surface layers (0-5 and 5-20 cm). The indicators that have been studied are bulk density, relative density, porosity, water resistance of soil aggregates, mechanical composition, active reaction (Ph H_2O) of soils, content of org. carbon (C, %) and total nitrogen (N, %), for the study of which generally accepted methods were used (Donov et al., 1974).

For dead leaf cover were determined the reaction (Ph), the content of carbon (C, %), total nitrogen (N, %) and holding capacity. The water holding capacity was determined for 12 and 24 hours. Each result obtained for the forest litter is the average of three separate measurements.

Results and discussion

The main tree species used for afforestation in the Bistritsa river watershed are white pine and black pine. In the higher parts of the watershed there are also planted forests of fir (*Abies alba* Miller). In this watershed, 5 sample areas were established, four of them in white pine and one in black pine, samples were also taken from two controls on meadow, situated on apparently undisturbed terrain. The characteristics of the areas are presented in table 1.

Table 1. Characteristics of sample areas in Bistritsa watershed

Type of forest	Altitude, m	Slope, °	Exposition	Age,y	Height, m	Afforestation scheme	№ Sample area
White pine	1000	32	Southwest	50	17	1.5x1.5	SA 1
White pine	1100	39	Northwest	60	16	1.5x1	SA 2
White pine	750	23	North	70	19	1.5x1.5	SA 3
White pine	750	18	North	55	20	1.5x1	SA 4
Black pine	700	18	North	55	20	1x1	SA 5
Meadow	800	9	Northwest	-	-	-	Control 1
Meadow	750	8	North	-	-	-	Control 2

The selected afforestation are located at an altitude of 700 to 1000 meters, mainly on shady slopes. All selected SA have a dense afforestation scheme, which is due to the goals of their creation.

The established soils characteristics for this watershed are presented in the table 2. In the analyzed samples, the amount of total nitrogen in the surface horizons is in the range of 0.04 to 0.16, which is lower than in some other investigated watershed with common characteristics (Pavlova-Traykova et al., 2018) and shows that the soils are poorly stocked with nitrogen. In this catchment, a high water resistance of the soil aggregates under the afforestation is established, and in the controls resistance of aggregates are low. Due to the intense erosion processes in the past in this catchment, the controls from the surface layer 5-20 cm are mainly composed of different sized hard rock particles, which made it impossible to apply a soil analysis for this layer.

The carbon content (C, %) varies from 0.93% to 4.86%, decreasing in depth. In SA 1, the results in the mechanical composition differ from the general trend. Such a distribution of the mechanical composition with little or no silt is characteristic of soils with the presence of erosion processes (Erzsebet, Gergely, 2001). The slope as the main factor of the erosion process can be determined as the reason for this difference. The slope in this SA is steep (32°), but in SA 2 is steeper (39°) and the mechanical composition resembles the trend in this watershed. For that reason, these results may be related to the different exposure and, accordingly, the different conditions in which all processes take place.

All analyzed soils have an acidic reaction (pH 5.09-5.56), which is characteristic of soils under coniferous. According to skeleton results, the soil samples from SA 2 and SA 3 are highly skeletal, and in the remaining soil samples the soils are low skeletal. From the obtained results for the bulk density, the soils in the watershed of the Bistrica River can be classified as light soils, which defines them as more vulnerable to soil-

Table 2. Soil characteristics

Sample area(SA)/ forest type	Depth, cm	pH (H_2O)	C, %	N, %	Soil skeleton , %	Q, g/sm³	D…	Porosity, %	Water resistance of soil aggregates, %	Mechanical composition, %		
										Sand	Clay	Silt
SA1/ White pine	0-5	5.24	0.93	0.11	23.04	1.60	1.3	30.43	100	86.99	13.01	-
	5-20	5.17	0.27	0.06	85.24	-	2.4	-	100	88.65	11.35	-
SA 2/ White pine	0-5	5.56	3.12	0.14	87.28	0.91	1.3	30	98	80.17	19.83	8.26
	5-20	5.60	2.91	0.13	71.38	-	2.3	-	99	81.29	18.71	4.16
SA 3/ White pine	0-5	5.36	4.86	0.16	71.33	1.29	2.2	41.36	100	86.73	13.27	4.09
	5-20	5.09	0.27	0.04	68.14	-	2.4	-	99	87.09	12.91	4.07
SA 4/ White pine	0-5	5.46	4.26	0.19	25.13	0.85	2.7	68.52	100	74.38	25.62	8.23
	5-20	5.11	1.64	0.11	26.83	-	2.2	-	97	70.4	29.6	12.51
SA 5/ Black pine	0-5	5.24	3.76	0.14	26.54	1.09	2.6	58.08	97.5	78.57	21.43	4.1
	5-20	5.33	0.87	0.08	41.36	-	1.1	-	97	78.49	21.51	12.17
Control 1	0-5	5.25	0.49	0.06	34.72	1.19	1.4	15	65.5	65.54	34.46	8.11
	5-20	-	-	-	-	-	-	-		-	-	-
Control 2	0-5	2.24	3.82	0.22	30.77	0.71	2.3	69.13	68	66.77	33.23	8.1
	5-20	-	-	-	-	-	-	-		-	-	-

destroying processes. The porosity of the soil samples is „very poor" to „unsatisfactory" for the soil samples from test areas 1, 2 and 3 and „very good" in the soil samples from test areas 4 and 5. Porosity mainly depends on the organic matter content. With „unsatisfactory" porosity, the soils are poorly permeable, precipitation cannot pass into the soil horizons, and this is a prerequisite for the formation of a large amount of surface water runoff.

Based on the data on the amount of water that the dead leaf cover retains, it was established that a litter of 400 cm^2 is able to retain an amount of water that is more than its own weight (table 3). At SA 1, it is three times the weight of the dead leaf cover in a dry state. A high water-holding capacity of the forest litter was also found at Badinska river (Pavlova-Traykova et al., 2018). In studies of other watersheds, Kitin (1984) and Marinov (1995) also found such a trend. In SA1 the content of carbon and nitrogen are the highest. All forest litter in the sample areas has an acidic reaction (pH - 5.4-5.68). The content of (C, %) in the analyzed samples (table 3) varies from 10.72 % in SA 5 to 25.21 % in SA 1. Nitrogen (N, %) varies within the range from 0.83% to 1.11%.

Table 3. Characteristics of dead leaf cover in Bistritsa watershed

Sample area/type of forest	pH, (H_2O)	C, %	N, %	Dry sample, g	After 12h,g	After 24h,g
SA 1/ White pine	5.05	25.21	1.11	691.95	2166.4	2352.99
SA 2/ White pine	5.17	22.69	1.06	611.67	1159.2	1178.6
SA 3/ White pine	5.4	13.99	0.83	457.97	1101.05	1219.21
SA 4/ White pine	5.68	16.81	0.88	679.39	1323.97	1347.53
SA 5/ Black pine	5.42	10.72	0.73	476.82	957.57	1015.22

In the watershed of the Dzhubrena River, the main tree species that are used for afforestation are white pine, black pine and acacia. In the watershed, 9 SA have been established (table 4), of which 4 are planted with white pine and 4 with black pine. Two controls under meadow are also studied.

The porosity in the surface 5 cm of the soils in the Dzhubrena River can be defined as „good" to „very good", and in SA 7 it is „unsatisfactory" (table 5). The good porosity indicates the high ability of the studied soils to fully absorb the fallen precipitation, thus reducing the surface water runoff. A high water resistance of the soil aggregates was found in all soil samples, while it was lower in the controls (from 70 to 79%), which shows the impact of forest vegetation on the soils. The content of physical clay is from 8.17% to 65.25%, of silt from 4.0% to 32.22%, and in the SA 4 there is no silt in the 0-5 cm layer. The absence of silt indicates weaker connectivity of soil aggregates, which is an indicator of less resistance to erosion processes in this SA. The content of clay, silt and organic matter are high in most of the samples, which helps to stabilize the soil aggregates and increase the resistance of the soil to the erosive force of water.

Table 4. Characteristics of sample areas in Dzhubrena watershed

Type of forest	Altitude, m	Slope, °	Exposition	Age, y	Height, m	Afforestation scheme	№ Sample area
White pine	750	7	Southeast	45	16	1x2.5	SA 1
White pine	800	6	Southeast	45	20	1x2.5	SA 2
White pine	750	14	Southeast	18	5	0.5x1	SA 3
White pine	950	23	Northeast	25	26	2.5x2.5	SA 4
Black pine	850	24	Northeast	60	23	0.5x2	SA 5
Black pine	900	16	Southwest	65	24	2x2.5	SA 6
Black pine	900	21	West	75	25	2x2	SA 7
Black pine	850	27	Northeast	60	24	2x2	SA 8
Meadow	850	12	Southwest	-	-	-	Control 1
Meadow	850	11	South	-	-	-	Control 2

Table 5. Soil characteristics

SA/Type of forest	Depth, cm	pH (H_2O)	C, %	N, %	Sceletion, %	Q, g/sm³	D	Porosity, %	Water resistance of soil aggregate, %	Mechanical composition, %		
										Sand	Clay	Silt
SA 1/ White pine	0-5	5.21	3.54	0.12	21.54	1.15	2.3	50	98	57.22	42.78	26.23
	5-20	4.95	1.87	0.06	71.62	-	2.4	-	99	54.11	45.89	32.22
SA 2/ White pine	0-5	5.13	4.49	0.14	43.61	1.12	2.7	58.52	100	75.42	24.58	8.16
	5-20	5.49	0.99	0.02	42.75	-	2.6	-	100	49.96	50.04	8.34
SA 3/ White pine	0-5	5.36	2.76	0.08	35.21	1.26	2.3	45.22	100	74.23	25.77	16.3
	5-20	5.40	2.74	0.08	44.08	-	2.3	-	100	66.30	33.70	16.44
SA 4/ White pine	0-5	4.51	1.45	0.05	26.3	1.6	2.7	40.74	99.5	83.71	16.29	-
	5-20	4.28	1.20	0.04	41.84	-	2,5	-	100	91.83	8.17	4.09
SA 5/ White pine	0-5	4.91	5.76	0.14	38.2	1.21	2.2	45	98	83.74	16.26	8.23
	5-20	4.80	2.25	0.07	50.24	-	2.3	-	100	83.46	16.54	12.4
SA 6/ Black pine	0-5	4.97	3.97	0.14	21.5	1.13	2.6	56.54	100	83.09	16.01	4
	5-20	4.94	1.71	0.06	21.1	-	2.6	-	98,5	83.68	16.32	8.16
SA 7/ Black pine	0-5	4.78	4.2	0.14	20.32	1.23	2.4	48.75	99	83.91	16.19	8.1
	5-20	4.78	0.95	0.03	31.38	-	2.2	-	100	83.79	16.21	12.15
SA 8/ Black pine	0-5	4.56	1.24	0.04	26.37	1.27	1.9	32.80	97	83.59	16.41	4.09
	5-20	4.45	0.48	0.02	45.72	-	2.2	-	94	87.54	12.46	4.15
Control 1	0-5	6.23	3.75	0.13	27.42	0.89	1.1	19.09	70.5	63.46	36.54	28.62
	5-20	6.02	3.23	0.08	23.15	-	2.0	-	73	67.32	32.68	4.56
Control 2	0-5	5.38	2.27	0.07	26.6	1.37	2.5	46.4	79	75.11	24.89	12.24
	5-20	5.41	2.08	0.566	22.15	-	2.3	-	73.5	60.93	39.07	12.51

All dead leaf cover has an acidic reaction, with pH values ranging from 4.48 to 6.24. The carbon content (C, %) varies from 13.92% to 33.55% (Table 6). Nitrogen (N, %) in litter varies from 0.36% to 0.98%. From the results obtained for the amount of water retained for 12 and 24 hours, it was found that the best water holding capacity was found in the forest litter in the pine afforestation.

Table 6. Characteristics of dead leaf cover in Dzhubrena watershed

SA/Type of forest	pH, (H_2O)	C, %	N, %	C:N	Dry sample, g	After 12h,g	After 24h,g
SA 1/ White pine	4.85	13.92	0.52	15.64	381.36	1384.23	1476.7
SA 2/ White pine	4.48	29.21	0.49	34.33	902.98	2387.6	2443.11
SA 3/ White pine	4.77	15.55	0.36	25.30	490. 78	994.2	1037.46
SA 4/ White pine	4.83	33.55	0.98	19.87	227.46	827.45	874.2
SA 5/ Black pine	5.02	31.33	0.82	22.20	568.53	1269.94	1314.5
SA 6/ Black pine	5.07	22.91	0.53	25.15	413.21	1380.18	1429.27
SA 7/ Black pine	4.91	21.10	0.47	25.85	387.24	735.99	767.25
SA 8/ Black pine	5.2	26.38	0.54	28.34	529.46	1713.81	1760.21

Conclusion

Positive effect of the created coniferous afforestation was established. In both watersheds a high water resistance of the soil aggregates under the planted forests is established, and in the controls resistance of aggregates is low. The obtained results for the organic C and total N showed that with lower altitude the content being higher. All SA have an acidic reaction.

In the Bistritsa river mechanical composition of the controls and the content mainly of different sized hard rock particles in the lower layers are indicative of the strong erosion processes in the past.

The presence of a high content of C and N in the dead leaf cover and, at the same time, their lowest content in the soil samples, shows that the processes of decomposition and soil formation proceed very slowly, and despite the high accumulation of nutrients in the forest litter, they do not have reached the soil layers. It is established a high water-holding capacity of the afforestation, especially in white pine crops.

References

Angelov St., Bachvarov D. 1963. On the corrective and strengthening works in the beds of some torrential water currents in Kardzali district. Notices of the Forest Institute. 89-122.

Appendix1.4file:///D:/Downloads/%D0%9F%D1%80%D0%B8%D0%BB%D0%BE%D0%B6%D0%B5%D0%BD%D0%B8%D0%B5%201.4.pdf

Erzsebet M., Gergely J. 2001. Soil erodibility values calculated on the basis of soil loss experiments (USLE). Foldrajzi Ertesito, 50, (1-4); 137-142.

Kittin B. 1984. Water-holding capacity of dead lea cover. Forestry Science, 6, 39-46.

Marinov Iv. Ts. 1995. Water-holding capacity of white pine afforestation. Forest Science, 1, 43-49.

Marinov Iv. Ts. 2011. Water runoff and eroded soil from small mountain watersheds in Malashevska Planina. International conference „100 years of soil science in Bulgaria", May 16-20. Sofia. II, 890-896. ISBN 978-954-749-088-8.

Panayotov M., Tsvetanov N, Gogushev G, Tsavkov E, Zlatanov T, Anev S., Ivanova A., Nedelin T, Zafirov N., Aleksandrov N., Dountchev A, Vasileva P., Shishkova V., Stoyanov B., Sotirova N., Vatov A., Bebi P., Yurukov S. 2016. Mountain coniferous forests in Bulgaria –structure and natural dynamics. University of Forestry, Sofia, 332 pp.

Pavlova-Traykova E. 2019. Evaluation of water erosion risk in Bistritsa river watershed, Southwest Bulgaria. Forest science, Issue 55, V1, p.53-63

Pavlova-Traykova E., Marinov I. Ts. 2018. Evaluation of water erosion risk in Dzhubrena watershed. Silva Balcanica. Issue 19 (3) p. 1-9.

Pavlova-Traykova E., Marinov I. Ts., Dimov P. 2018. Analysis of erosion controll activities in the Badinska Reka torrent. II. Afforestation. Forest Science, Vol 1. 55-68.

Pavlova-Traykova E., Nedkov S., Zhiyanski M. 2021. Integral approach to the flood protection effect of forest with special consideration of erosion control in Bulgaria: review. Collection of reports from the Eleventh Scientific Seminar of the Forest Research Institute - BAS, dedicated to Prof. Dr. Emil Borisov Popov, Forest Research Institute, 2021, ISBN:978-619-7228-07-6, 77-87

Popov G., Kostov G., Markov Iv., Dodev I., Georgieva D. 2018. Coniferous plantations in Bulgaria created outside their natural areal. Sofia Pre-press preparation: D. Georgieva Print: Document Center „Avangard" Publisher: „Avangard Prima" ISBN 978-619-239-044-0, 121

Regulation 2 .2013. On the condition and procedure for afforestation of forest territories and agricultural lands used for the creation of special, protective and economy forest and of forest in protective territories. https://lex.bg/laws/ldoc/2135838160